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by

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Zenon S. Zannetos*

I. Introduction

My presentation will be concerned with information systems and their role in the management process. Having chosen to talk in particular about new directions in information system design, I realize that to a certain extent my presentation may be controversial as well as speculative. So I feel that I owe you this warning. But I do not believe, however, that I owe any apologies for addressing you at a conceptual level, for several reasons. First of all, if I am to concentrate on things to come, of necessity I will not be able to give you results based on actual operating experience with such systems, because such systems have not been applied as yet. More important, however, is the fact that I do not want to insult your intelligence and ingenuity by talking to you about the "bolts and nuts" of the present and past. I will, however, wherever I can, describe the operating characteristics of these future systems and and also give you an idea as to how one can go about implementing them. Finally, I would urge you to bring up questions about detail during the discussion.

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*The author is Professor of Management in the Alfred P. Sloan School of Management of the Massachusetts Institute of Technology. This paper is based on points raised by the author at the meeting sponsored by the MIT Club of Washington on February 18 and the Seminar of The Maritime Management Institute of the Maritime College, State University of New York on February 25, 1967.

In order to introduce my subject, I would like for a moment to spend a few minutes on the assumptions behind the various issues that I will take up. Some of these assumptions may appear on the surface to be obvious, but their consequences may not. So a brief discussion may help our understanding of the issues involved and also provide a rationale for the transition from present to future systems.

To the extent that information helps learning, through hypotheses elimination, it is a behavior-motivating factor. Different types of information can produce different consequences. The information system could, therefore, be used to influence people to channel their resources and those of others in an efficient way. But the notion of measurable efficiency is neither easy to establish nor is it determinable in an esoteric sense. It can be established only relatively to the overall objectives of the particular organization. The objectives of the information system, as a result, can be nothing more than a reflection of the organizational objectives. That is why the design of the information system and that of the organization structure are two sides of the same coin.

Having come to the realization that the efficiency of the information system can only be measured in terms of how well it helps the organization achieve its particular objectives, we may now ask: Can we, therefore, talk about general overall objectives of system design? Unless we can answer this question in the affirmative, there will be no way we can justify our research efforts to develop a general theory for design of information systems. Naturally each system will be a particular system whose efficiency cannot be comparatively assessed on the basis of some empirically feasible and universal criteria.

II. Objectives Derived from the Management Process

If universal objectives for the information system cannot be derived in an ultimate teleological sense, then we can look at the management process. We find that not only management is necessary in every situation irrespective of the end objectives, but that it also depends on subprocesses which are equally universal. Planning and control are two functions characteristic of every management situation, and these functions in turn are based on indecomposable decision modules. The information system, as a consequence, must derive its objectives from these universal characteristics.

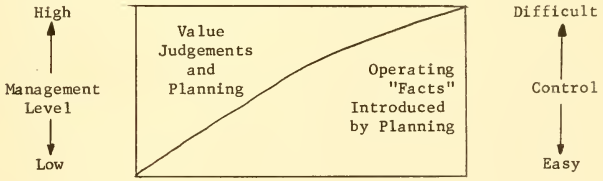
As I view it, management information systems have two major purposes: 1. To facilitate managerial planning and control, that is to say, to help management plan better and also control the operations which are necessary to implement the plans and 2. Relieve management of all the repetitive tasks so that they (the managers) can concentrate on planning.

In the context used here, planning is viewed as the process by means of which managers choose appropriate objectives and also the means for their implementation. It includes the transformation of objectives into operationally meaningful subobjectives and the design of the information system which is necessary for control purposes. In this sense, planning sets the structure and the "straightjacket" within which operations take place. It orders the environment and presents the value judgements of high-level planners as facts on the basis of which lower level managers operate. Obviously, the greater the resolution and detail that are introduced by high levels in the management hierarchy, the lower the value-judgement content of low level managerial decisions and the more restrictive is the environment within which these managers operate. That is why it is very important

to study the planning process. It makes little sense to break our necks to improve day to day operations and neglect planning which fixes resources and prejudices operations for years to come.

Planning in its totality, is a dynamic, nonrepetitive (in its detailed characteristics) and time-interdependent (sequentially adaptive) process. It must be distinguished from policy which is a static notion and refers to repetitive situations. In effect, policy is a procedure which tells us what to do whenever we meet similar situations.

Control is the process by means of which measurements are applied and signals are generated to show how well operations are conforming to the postulated plans. Notice that the greater the amount of factual elements that are introduced by the planning process the easier it is to regiment and control the operations. This can be seen in the diagram presented here.



The Planning Process

Control is an integral part of the total planning process. For those who are familiar with engineering systems, the control system which will be implied in my subsequent discussion is similar to a closed-loop system where the control unit is part of the process which it attempts to control. One of the simplest and most unintelligent closed-loop control systems is the thermostat which we use in home heating. It has a sensor to observe the temperature, a mechanism by means of which the desired setting is indicated, and a control unit which reacts and turns on the furnace, on the basis of an observed difference between the temperature and the desired setting. If the control unit was not part of the process, then we would have to depend on the sensitivity to temperature changes and fidelity of an outside controller. For example we would have to sense the changes ourselves or else remember to observe the actual temperature and then on the basis of our observation turn on the furnace.

The thermostat is very unintelligent because it does not understand what is going on (cause and effect relationships). It only addresses itself to the symptom. The managerial control systems, must be more intelligent especially if they are to help in planning. They must be capable of performing diagnoses and more important prognoses so as to allow the planner enough time between the time he receives the signal and the point in time when an undesirable event will take place if certain preventive steps are not taken. Most of our managerial information systems today, and for sure the accounting systems are of the post mortem variety.

No one, I trust, will take issue with the first assumption that the role of management information systems is to facilitate planning and control. I am sure, however, that there will be many people who will feel uncomfortable with some of the consequences of the second.

I postulated as a second objective of the management information system, a capability to take over, from management, all the repetitive and programmable aspects of planning and control and allow management by exception. In effect, the second assumption postulates that the system be used as an extension to human capacity and intelligence, and as a stepping stone to higher level planning and control.

If we look into the process of allocation of scarce resources, we will find that management and the information system normally focus their attention on day to day operations. As long as variances are not evident everybody is happy. (In contrast the systems which we will suggest imply that there is something seriously wrong if variances are consistently close to zero.) The higher level processes, i.e. the process by means of which operations are carried out, the nature of the relevant decisions, the decision-making process itself, the chosen plan, and the planning process are mostly left outside the purview of the information and control system and are carried out, if at all, on an ad hoc basis.

The present information systems have the capability to store data (as long as unused storage capacity exists), classify them on the basis of some prestored rules and extract differences (variances). The latter indicate the potential existence of problems. In order to serve as an extension of human intelligence, however, the information systems must be able to store

cause and effect relationships (models), check on the validity of such relationships and ultimately recognize patterns of relationships on the basis of incomplete information, i.e. recognize the total picture before all the pieces of the mosaic fall into place.

I said that some people may find arguments in the above assumption, mainly because of the thought of human beings, being manipulated by inanimate computerized systems and also because many believe that management information systems can possess no intelligence. These fears of course are exaggerated. I hope to convince you that intelligence can in no way be of danger to human beings. This, as you may know, has been an issue which has been debated extensively and in the process has generated a lot of emotional outbursts. Admittedly, psychologically some managers may feel that they will be relinquishing control if their system is computerized because they know nothing about computers. But do they have to know at present the debits and credits of the accountant before they can use the output of the accounting process?

III. Assumptions Concerning Human Nature

There is another set of assumptions inherent in my arguments, which assumptions refer to human nature. It appears that human beings have certain characteristics of intelligence which are very important for us and which we must imitate if we are to design efficient information systems for planning and control. First of all, if we want the system to serve as an extension of human intelligence, our systems must imitate human thought. Second, since the information that is generated by the managerial system is aimed at motivating managers to learn and perform better, we have to know how people

perceive information, how they are motivated on the basis of such perception, how do they associate cause and effect, and how do they react to such associations? We do not want symptomatic reactions and symptom cures, but fundamental causal diagnosis.

Among the assumptions concerning human nature that are important to us, we include: 1) limited capacity: by this I mean limited storage capacity in our brain to the point where we have to be selective in what information we store and what we don't. There are some people who argue that we do not have such limitations and that practically we have infinite capacity for storage and manipulation. According to the experts the human brain can store up to 10 billion bits of information. No matter how large such a number may appear on the surface, it is not sufficient to store all there is to know if everything had to be stored in a raw data form. Furthermore, there would be no space left for higher-level processes such as perception, transformation, association, deduction and induction. But whether or not we accept the unlimited capacity doctrine, our subsequent arguments are not prejudiced as long as we can agree that automatic retrieval of stored information is much easier if it is stored neatly and associated in terms of patterns rather than having to be retrieved bit by bit. In other words, whether or not we have limited capacity is not as important as the fact that we have what we may call memory which is facilitated if the stored information is related to some context rather than stored independently of some cues characteristic of the environment which generated such information. Also the greater the applicability of the causal relationships the more powerful these are and at the same time the lower are the storage requirements. We do sacrifice, however, some speed in retrieval or recall of such information.

2) limited rationality. This assumption behind human nature implies that people are not completely rational with respect to every objective. The reason being that the objective itself is not universally held. That is to say, given that all of us do not completely agree, on a given objective, by definition, if such an objective is accepted as a universal or a group objective, the people who disagree with it are viewed within this context as possessing limited rationality. The information systems help increase this rationality by providing signals which motivate people to associate cause and effect and they do not, therefore, unwittingly substitute their individual goals for the organizational objectives.

3) desire to order the environment. This is one of the most critical assumptions behind human nature and one which affects the design of the information systems extensively. It implies that by nature people try to classify, organize and create structures and niches in order to store information. Among other things, this property of human beings implies that in order to solve problems we have to develop some procedures by means of which we can first recognize the existence of problems, compartmentalize them, associate parts with other known similar situations, develop plans for solution, apply the techniques that we draw from our experience to solve the particular parts of the problem and finally fit the parts into the total. Hopefully, we will at the end succeed in solving the problem in its totality. The next step, of course, is to develop a plan for solving similar problems.

4) an aversion toward uncertainty. That is to say the desire to stay within an ordered environment rather than to venture into the unknown.

It is very important to realize here the conflict between assumptions 3 and 4 as stated above. The desire of human beings to order and structure the environment is conducive to progress and learning, but the aversion toward uncertainty inhibits progress. That is perhaps why we often find that the greatest impediment to further progress are successful innovators. (Little do they realize that their very success renders their own method obsolete once it becomes known and it is imitated.) The greatest revolutionaries often turn into the greatest conservatives and as a result the revolutionary process stops. If, we could somehow, succeed in continuously thrusting an individual in an unstructured environment then we can capitalize on the great innate capabilities that he has to create order out of chaos and therefore advance learning. Once he arrives there, however, unless once again the system motivates him to venture into the unknown or throws him into a new state of uncertainty, he will have a tendency to stay there and stagnate having been regimented by the very structure he himself created.

It is not, of course, surprising that we notice these conflicting tendencies. After all, it is the fate of managers to reconcile interdependencies and also resolve situations where alternatives are available. Obviously, if alternatives are not available, there will be no premises for decisions and no premises for establishing tradeoffs among them.

The above imply that we need control in order that we be able to order the unstructured situation. But we must also recognize that control has a

tendency to regiment and that there is a danger that it may become an end in itself due to the human fear of the unknown. Many of those who have argued against controls, they have not necessarily argued for its abolition but against its misuse. And here we see that unless control is relinquished once an advanced understanding is achieved, and unless this level of understanding is used as a stepping stone to once again venture into the unknown and achieve higher level solutions, stagnation and regimentation will no doubt result.

Another thing that is clear from the above discussion is that the individual, unless consciously directed, will attend to the short-range problems and firefighting that are presented before him and neglect the long-range aspects of planning and control. And this, because long-range planning involves estimation and forecasting, that is to say, presupposes an excursion into the unknown which makes many people uncomfortable. That is why long-range planning often is done intuitively on a memorandum basis or none at all, and a lot of firefighting occupies the life of many exeuctives. This process as you may have noticed is degenerative. The more a person firefights the less time he has to spend on planning, and the less time he spends on planning the more he has to firefight. This is a vicious circle. The purpose of the information systems that we are developing is to relieve managers from all these repetitive tasks that can be successfully introduced into the system itself, let the system monitor and control operations on the basis of the plans, provide managers with the results of the control process on a selective basis and let them decide on issues for which no routine has been provided or established. But above all, give managers time for more

formalized planning so that they can eventually develop an inventory of planning knowledge. At present we have nothing to capture the experience of planners, store such experience for future recall by themselves and others. We depend on training through apprenticeship. Can you imagine what will happen if we continue extending the frontiers of knowledge in the area of management and yet keep on training through apprenticeship? The trainee will retire before graduating into the managerial ranks. Obviously we cannot afford such eventualities, nor can we allow planning to be done haphazardly.

IV. Where do we start?

The next question of course is where do we start in this process of developing intelligent information systems. Naturally, it is much easier to start from a structured situation rather than completely ignore existing systems and start from scratch. There are some good characteristics of some existing systems which we can capitalize on. For example, the existing standard systems with flexible budgets provide us a good basis for future systems. These systems enforce estimation and formalized models. What is more, they can be closed-loop systems, and can be applied to other than manufacturing operations. The first thing that we can do to improve a standard cost system is to enable the system itself to assess the significance of the observed differences rather than throw everything into the lap of managers. You, no doubt, are familiar with all the data which are generated today by the accounting system (the latter is very low in the hierarchy of intelligence as sketched here). These data are pushed across the desks of managers and force the manager to scan through literally

thousands of entries and question significance. Often, the recipient of these reports is hopelessly lost for he cannot determine what is important to observe and what is not. His time is very valuable and extremely limited, therefore, he is often forced to completely ignore them and decide on intuition. This process has some very grave consequence. Not only a lot of cost is expended on information gathering and processing for a very limited purpose, if any at all, but in addition the manager is forced to conduct a lot of post mortems which could have been avoided had there been an effective system to sense trouble while it was going on and before a lot of wastage of resources takes place. It is imperative that we help the manager utilize his time more effectively. We can do this by asking him what rules he applies in determining what is significant and what is not, introduce, and very easily I might add, such information into the system and trust it from then on to do the first sifting and report only the significant variations.

Obviously, a system such as this which can operate on sampled information will not only be much better but also cheaper in terms of implementation. In the few cases that I have studied only one per cent of the present data transmitted to managers is important enough to merit their attention. If, therefore, changes are made along the lines alluded here, (and suggested in more detail in the references included in the bibliography) not only substantial savings will result, but also the manager will no longer spend his time over data which have little, if any significance. He will be able to concentrate on the few that need his attention and also will encourage him to plan a structure for even some of those situations that are now decided by him, derive cause and effect relationships, learn how to perform better

and also inductively learn how to generalize about problems of more general significance within the same class of problems. As I have already mentioned, the techniques for implementing a simple probabilistic system exist today. A lot of work on managerial models is already behind us and the only thing we need is to formalize these models by introducing them into the continuous information system of the firm. Once this is done, then control limits similar to those imposed by quality control engineers can be applied in order to determine what is significant and what is not, and on the basis of the result of this selective process an analysis of the few significant variations will be performed in order to find cause and effect relationships, only to be introduced in the next round into the information system for subsequent validation. Modern statistical techniques allow us to marry intuition with objective observations and sequentially apply the cumulative experience of the information system for validation of the models that we use. And this unlike the present accounting systems which close out the variances, and look at periodic results in isolation, and in the process destroy the statistical universe from which inferences can be derived about the underlying cause and effect relationships.

As you can see, I am suggesting a continuously upgrading process, but we need not stop here. We can also question as to whether we can generalize on the basis of these cause and effect relationships and help subunits reconcile their interdependencies within an existing organization. We have already stressed that in order to be able to solve problems and deal with uncertainty, we structure the environment and compartmentalize the task facing us. The operations of the firm are nothing more than an effort

to provide a solution to a complex problem, namely the implementation or the achievement of the objectives of the firm. Given that any such structure is temporary, unless it is consciously used as a stepping stone to a higher level solution, it will regiment and lead to stagnation. [see 7] We must, therefore, try to provide as part of the regular information process, routine signals on the possible advisability of an organizational restructuring. This is a topic that I have been studying and described elsewhere [see 4], and which focuses on the covariances (i.e. how the performance of sub-entities varies with causes originating elsewhere within the organization). A very good attribute of such analysis is that among the components of such covariances are the statistical and accounting variances generated by the system as part of the routine operational control. So for the first time now we can get signals on possible reorganizations as part of our regular information flows. The analysis of covariances and the design of experiments that follows to determine cause-effect relationships will help tremendously in formalizing models, facilitating planning, and giving prognostic signals to interrelated subunits. For example, many of the cause and effect relationships may incorporate time lags. Once the system, as a result, picks up a significant variation in subunit X which will have an impact on subunit Y, say two months hence, then unit Y is warned of the impending consequences of such variances. The manager of unit Y in this way has two months to plan in anticipation of the impact rather than wait and plan by crisis. As you can readily see, the value of such information is tremendous. And this because of all the alternatives that are available to the managers (during the lead time between the manifestation of the signal and the consequences if no action is taken) to avoid wasting resources.

The power of such a system can be measured in terms of the uncertainty that it succeeds in eliminating. When covariations are negative, joint planning (relative centralization) often pays off, while positive co-variations often necessitate information filtering and further buffering to bolster independence. These are consequences of the study of the covariance matrices.

Finally, we would like to see whether the information system itself can recognize patterns of relationships and of configurations of resources and also the context within which these are meaningful so that it can associate a signal with an existing pattern within the firm. Now we enter into the field of pattern recognition and artificial intelligence and what we call associative and adaptive information systems. The technology here is not so well developed. And by this we mean, not only in a hardware and software sense, but also at the philosophical and conceptual level. Therefore the only thing I can tell you now is that I and several others at MIT are spending a lot of time in trying to solve some of these difficult problems. [see 1 and 7] The results are somewhat encouraging but for sure we are not there yet.

During my presentation I concentrated mostly on the economic-rational issues and bypassed without prejudice a lot of the behavioral. Now I would like to address myself briefly to the latter issues and conclude.

It was not long ago that a former colleague, the late Douglas McGregor, made an eloquent plea for freeing the individual from the bondage of enterprise management controls. What he was decrying was not so much the existence of controls, for we can readily see that we need them for economic reasons (the realization of economies of large-scale production) and the reconciliation

of interdependencies among complementary resources within an extremely complex probabilistic setting. He was concerned about controls which produce undesirable consequences in terms of the overall objectives of an organization.

No matter how compelling the arguments of people in the field of human relations are, I believe that there are many observations which they attribute to subjective behavior and which can be explained by purely objective reasons. One such example is the conclusion by some people that mutual interaction structures are better than hierarchical structures. If we look at the settings which these researchers used as laboratories for experimentation, we often find that the tasks they chose to observe were of the type that needed mutual interaction because of the extreme complementarity among subtasks or individual proficiencies. As a matter of crude analogy, if a person drinks his coffee with cream and sugar he mixes them together, he does not drink them separately. In the case of substitutable or competitive tasks, however, there is no reason why people must be brought together.

I am confident that in the future we will hear less and less about this concern of regimentative human controls. And this not because the issue will disappear, but because a more compelling reason that of the human dependence on computers, (which will be far more worrisome), will take its place.

In the absence of computers there were at least two factors which served to mitigate the impact of suppressive managerial controls.

1. The inability of human beings to expand ad infinitum the scope of centralized controls and manage such a system successfully. Some refer to evidences of this problem as negative decentralization.

2. The greater opportunity for a human dialogue

Actually, our experience with impersonal (computerized) controls may not prove to be that bad afterall. Many people may find a man-machine dialogue much more satisfying than a superior-subordinate encounter. Obviously the computer does not sit in evaluation sessions for promotions and raises. Nor do people mind it as much if it talks back at them. One thing, however, that a system such as the one I propose may do is to bring people who affect each other's performance together voluntarily for joint planning, once they realize their interdependence.

Computers benefit us extensively in many areas of management but also increase the potential of centralized systems where centralization is by nature favored. They may also increase passivity, submissiveness and anonymity through the elimination of middle management levels. Even as top managers what you see in the future you may not completely like. Because you may feel that the system is running away from you and with it the loyalty of people and the control of the organization. If you are not careful, you may find yourselves strapped to a system which tries to justify the very expensive tool that you acquired. Once the system is designed and installed, the damage is done. It is not easy to dismiss it as you can dismiss a payroll clerk. The inflexibility and specialization of data structures and software packages is enormous. The only way to guarantee that the system will effectively serve you as managers in your planning and control activities and serve as an extension of your intelligence is by influencing its design. This is a very serious matter and cannot be left, without painful consequences to the systems engineer.

In trying to find a parting thought about computerized information systems, I find that I am at a loss because of the vastness of this subject. But I want to say one thing by analogy. Computerized systems remind me of that little girl in children's nursery rhymes "who had a little curl right in the middle of her forehead. When she was good she was very very good. But when she was bad, she was horrid."

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